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Abstract

non-linear MHD simulations for ITER

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Non-linear MHD Simulations for ITER

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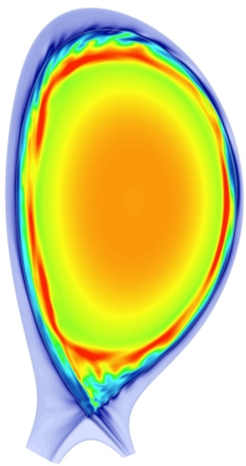
Validation of MHD models and non-linear MHD simulations on current experiments is needed to provide a firm physics basis for the application of these models to ITER. This paper describes the progress made towards validation in the area of the stability of the H-mode edge pedestal and ELM control.

ELM control: pellet pacing

The injection of small deuterium pellets is one of the methods foreseen to control ELM energy losses and divertor power fluxes in ITER. In DIII-D it was shown [1] that high frequency pellet injection can significantly reduce the magnitude of the ELM energy loss and of the divertor power fluxes with pellets as small as 0.9mm (~1.0 10^{20} D atoms). In JET with the ITER-like wall, pellets larger than 10^{21} D atoms are needed to trigger ELMs with a probability above 60% [2]. Extrapolation of the minimum pellet size to ITER requires a validated physics model to the ELM trigger process. Results from non-linear MHD simulations using the JOREK code [3] of pacing pellets injected in DIII-D have previously shown that the minimum pellet size is correlated with the minimum 3D pressure perturbation, created by the pellet, to destabilise a ballooning instability. This analysis has been extended to the non-linear MHD simulation of pacing pellets injected in JET discharges. The computational domain has been extended to include the x-point geometry, open field lines and divertor. This allows the simulation of a full pellet triggered ELM cycle, i.e. to study the non-linear consequences of a pellet triggered instability and determine the ELM energy and particle losses. The figure shows an example of a MHD simulation of an ELM triggered by a pellet in JET discharge #82885. In this case, with the pedestal close to marginal stability, the ELM energy loss is about 66kJ ($\Delta W/W \sim 2.3\%$), compared to observed ELM sizes between 100 and 250 kJ. The simulated ELM size is found to depend on the pedestal properties of the target plasma. For an L-mode like edge, no ELM trigger is found, although instabilities may be triggered further inwards. At reduced pedestal pressure gradients, well below the stability limit, only very small ELMs are found in the simulations. A detailed scan of the influence of the pedestal will show how close to marginal stability the pedestal needs to be to develop an ELM of significant amplitude.



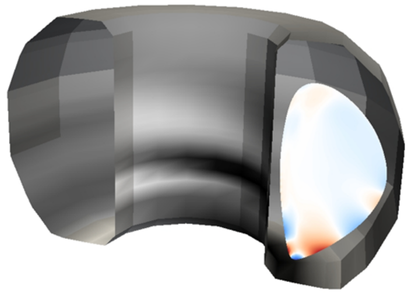
Density profile in JET pellet triggered ELM simulation

The pellet induces a magnetic perturbation in the plasma edge, leading to an ergodised edge. This ergodisation, similar to the case of natural ELMs and RMP stabilised plasmas, contributes to the parallel heat conduction losses during the ELM.

The divertor heat load due to the pellet triggered ELMs shows a characteristic n=1 asymmetry as a function of the toroidal angle for the low field side pellet injection (also observed experimentally [4]). The asymmetry corresponds to a secondary maximum in the power deposition profile on the outer target with an n=1 spiral structure. The paper will discuss the dependence of the power deposition asymmetry on the injection geometry and the consequences for ITER.

ELM control: QH-mode

Recently, DIII-D has made significant progress in the development of ELM free QH mode plasmas in an ITER relevant regime [5], using the RMP coils to control the rotation profile. Although not formally included in the ITER scenarios at this moment, an assessment is needed to determine whether QH mode plasmas may be a viable option for ELM control in ITER. To further develop the relevant physics basis for ITER, non-linear MHD simulations of DIII-D QH-mode plasmas have been performed. To be able to study the Edge Harmonic Oscillation (EHO), the JOREK code has been coupled with the STARWALL code [6]. STARWALL solves the linear equations in the vacuum and an arbitrarily shaped (thin) resistive wall, providing the free-boundary boundary conditions for JOREK. This has been successfully benchmarked on VDEs and resistive wall modes. The figure shows a 3D stationary state with a rotating saturated external kink mode, from a non-linear MHD simulation of DIII-D discharge #145117, including a toroidally symmetric DIII-D vessel. The influence of the poloidal and toroidal rotation and rotation shear on the stability and saturation of the kink mode will be investigated and compared with DIII-D experiments.



Stationary external kink mode (DIII-D #145117, perturbed poloidal flux and wall currents)

SOL MHD stability

Recent observations [7] of λ_q, the SOL heat flux width of the inter-ELM scrape-off layer (SOL) for low density H-modes with attached low recycling divertors, show a clear inverse dependence on the poloidal field and no significant scaling with any other parameter. Extrapolating such observations directly to ITER results in a very narrow $\lambda_q \sim 1$ mm. The MHD stability limits of the associated small scale lengths of the pressure profile have been analysed to evaluate whether MHD limits could prevent such narrow profiles. ITER scenarios with narrow λ_q are found to be stable to infinite-n ballooning modes. A comparison of n=20-40 ballooning mode stability on the open field line in the SOL and in the pedestal shows a higher (by ~40%) stability limit in the SOL. This indicates that the narrow λ_q (1.5-2.4mm) are consistent with MHD stability limits.

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